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ABSTRACT

Use of the computer in the design and operation of broadband communication systems are discussed. The current status of computer aided design is reviewed, with consideration ranging from components to total systems and networks. Future applications of computers to design, simulation, operation, maintenance, and economic modeling and decision-making are introduced and assessed. Lastly, recommendations are made for necessary future research and development. (Author)

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A SURVEY OF TECHNICAL REQUIREMENTS FOR BROADBAND CABLE TELESERVICES VOLUME 6

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VOLUME 6
THE USE OF COMPUTERS IN CATV TWO-WAY COMMUNICATIONS SYSTEMS

LARRY J. CAMPBELL

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FOREWORD

As information transfer becomes more important to all levels of society, a number of new telecommunication services to homes and between institutions will be required. Many of these services may require broadband transmission. The new services may, in part, evolve from those provided by cable television.

This is one of a series of reports resulting from a survey of the CATV industry and related technological industries. The survey identifies some of the important technical factors which need to be considered in order to successfully bring about the transition from the technical state of today's cable television and services to those new teleservices which seem to be possible in the future.

The current and future broadband capabilities of telephone networks are not discussed since they are described in many Bell Laboratory and other telephone company publications. Also, the tremendous load projected for common carrier telephone and data systems in voice and data communication suggests that two-way, interactive, broadband networks, not now in existence may be required in addition to an expanded telephone network. The many aspects of economic viability, regulation, social demand, and other factors that must be considered before the expectation of the new teleservices can be fulfilled are not within the scope of these reports. These reports concentrate on technical factors, not because they are most important, but because they have been less considered.

A report about the state-of-the-art and projections of future requirements in a complete technology draws material from a vast number of sources. While many of these are referenced in the text, much information has been obtained in discussions with operators, manufacturers, and consulting engineers in the CATV industry. Members of

the National Cable Television Association, particularly, have been most helpful in providing information, discussing various technical problems, and in reviewing these reports.

Because of the substantial amount of material to be discussed it was believed most desirable to present a series of reports. Each individual report pertains to a sub-element of the total system. However, since some technical factors are common to more than one sub-component of the system, a reader of all the reports will recognize a degree of redundancy in the material presented. This is necessary to make each report complete for its own purpose.

The title of the report series is: A Survey of Technical Requirements for Broadband Cable Teleservices. The seven volumes in the series will carry a common report number: OTR 73-13. The individual reports in the series are sub-titled as:

A Summary of Technical Problems Associated with Broadband Cable Teleservices Development, OT Report No. 73-13, Volume 1.

Subscriber Terminals and Network Interface, OT Report No. 73-13, Volume 2.

Signal Transmission and Delivery Between Head-End and Subscriber Terminals, OT Report No. 73-13, Volume 3.

System Control Facilities: Head-Ends and Central Processors, OT Report 73-13, Volume 4.

System Interconnections, OT Report No. 73-13, Volume 5.

The Use of Computers in CATV two-way Communication Systems, OT Report No. 73-13, Volume 6.

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THE USE OF COMPUTERS
IN
CATV TWO-WAY COMMUNICATION SYSTEMS

Larry J. Campbell*

Abstract

Uses of the computer in the design and operation of broadband communication systems are discussed. The current status of computer aided design is reviewed, with consideration ranging from components to total systems and networks. Future applications of computers to design, simulation, operation, maintenance, and economic modeling and decision making are introduced and assessed. Lastly, recommendations are made for necessary future research and development.

1. INTRODUCTION

This report discusses the use of the computer in the design and operation of broadband communication systems commonly known as CATV or cable television. The use of the term broadband here denotes more than the conventional one-way cable television; this discussion includes a full two-way communication between subscriber and the head-end of the system. This report also denotes future areas where the computer is expected to be utilized in both design and operation of CATV two-way communications systems.

Historically, CATV systems grew out of the need to transport TV signals into areas of poor reception due to the line-of-sight propagation limitations in the assigned VHF-UHF channels. Hence, the design of a system was a straightforward matter of providing a system with an

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adequate head-end (usually an antenna to intercept an existing broadcast station) and a distribution system with adequate gain to compensate for distribution losses in the system. As the CATV system grew longer, improved distribution systems became a necessity. The advent of solid state amplifiers and attendant computer aided design techniques were applied to distribution amplifiers. Hence, one of the early uses of computer aided design (CAD) techniques was in amplifier designs (Besser, 1970). Other early usage of CAD involved usage of existing propagation and interference models to locate head-end equipment (Naugle, 1970). The use of CAD is due mainly to increasing complexity of CATV networks and economic considerations of being able to accurately model a design before committing hardware to installation. Furthermore, the increased availability of computer aided design programs that adequately represent the physical characteristics of the devices and the application have made it attractive to designers of CATV equipment.

1.1 Evolution of Computer Aided Design (CAD)

Computer aided design has evolved with the advent of analog and digital elements that allowed the solution of complex mathematical relationships which represent real world systems. In order to solve these relationships for complex systems, two basic approaches have evolved. The analog approach basically is a parallel continuous system that can represent many time dependent functions using an analog of the processes being simulated. Extensive use of the analog approach has been made by the designers of control systems and in the development of aircraft and space vehicles where many simultaneous differential equations must be solved in order to evaluate system performance. Today analog simulation techniques are widely available on digital computer systems.

The second basic approach has been the simulation of discrete systems where entities exist in integral quantities and can be represented in discrete increments of time. This type of simulation has been applied in the areas of network analysis and queuing theory in order to optimize the flow and the use of facilities committed to the system against time and cost.

A brief discussion of two general purpose simulation languages that have application in CATV system design is presented here. The use of these languages to simulate an entire CATV system can be postulated as system complexity grows.

1.2 Continuous System Simulation

The Continuous System Modeling Program (CSMP) developed by IBM for their 360/370 series of computers is one continuous systems simulation language which is widely used and is one of many languages developed by various computer manufacturers. It is cited here as a typical language in this area, and it is a "digital analog simulator" in which the functional blocks of the input language represent the elements and organization of an analog computer. It includes a complement of standard analog elements, plus a group of special elements that the user can specify for his particular simulation needs. Each element type is provided with a diagrammatic symbol and a language symbol. The user develops a block diagram showing the interconnections of the elements required to implement his model, and then translates the diagram into a corresponding set of CSMP language statements.

Input and output are simplified by means of a free format for data entry and user-oriented input and output control statements. Data and control statements may be entered in any order and may be intermixed with structure statements. Output options include printing of

variables in standard tabular format, print-plotting in graphic form, and preparation of a data set for user-prepared graphic programs.

Two important features of CSMP are statement sequencing and a choice of integration methods. With few exceptions, structure statements may be written in any order and, at the user's option, may be automatically sorted by the system to establish the correct information flow. Centralized integration is used to ensure that all integrator outputs are computed simulateneously at the end of the integration cycle. CSMP provides a large complement of functional blocks (also called functions) for modeling a continuous system. These functions include such conventional analog computer components as integrators and relays plus many special purpose functions such as delay time, zero-order hold, dead space, and limiter functions. This complement is augmented by FORTRAN library functions such as cosine, tangent, and absolute value. In addition, the user can define functional blocks especially suited to his own application area. The definition can be accomplished either through FORTRAN programming or, more simply, through a macro capability that permits individual existing functions to be combined into a larger functional block. By combining these functional blocks with FORTRAN algebraic and logical statements, the user may handle very complex nonlinear and time-variant problems. The application of a CSMP type language to CATV system design would be useful, especially in the functions that can be represented in terms of transfer functions. Continuous system analysis has been traditionally performed in receiver designs and in determing interference generation and response of transmitters and receivers. The use of this type of analysis in the design of CATV equipment is expected to continue to grow.

1.3 Discrete System Simulation

Certain CATV system simulation involved elements that can be represented by a sequence of logical events can be more readily handled by discrete system models.

A typical discrete system simulation language is the Simscript (Kiviat, 1968) langauge, which was designed to overcome the repetitive work by producing machine programming with relatively minor effort on the users part. Simscript was developed as a convenient notation for the formulation of models and provides the analyst with a tool for the expression of the problem and measurement of the results. Programming time is reduced several fold as compared to programs written in FORTRAN and similar languages and is easily modified or expanded as the need arises. Widespread use of Simscript has made the language readily available on most modern computer systems in the medium to large scale categories. Discrete system simulation in CATV applications would undoubtedly be useful in the analysis of subscriber response times in a large CATV two-way system. Since response time can be formalized using queuing theory and a discrete system model can be expressed in Simscript terms, solutions to varing traffic loads can be analyzed.

1.4 Use of Computers in CATV Two-Way Systems

The preceeding general discussion of computer aided design has indicated that the use of computers in CATV and two-way communication systems offers the following advantages to both the designer and the system operator.

(a) Increasing complexity and size of systems to be installed,

(b) The need for accuracy in the initial design becomes increasingly important as system complexity increases,

(c) The need for flexibility and modularity in the design of a CATV system can be achieved by simulation by allowing the designer a list of acceptable solutions for given

variations. This factor is peculiarly important in a technology that is rapidly changing during the system life cycle.

(d) Increasing requirements for reliability becomes necessary when the complexity of a system increases. The trade-offs of system orgainzation and design can be the subject of parametric variations in key system attributes before actual installation,

(e) The necessity for documentation of the system is required due to the changing requirements during the life cycle of the CATV system,

(f) The improvement of the cost-to-performance ratio of modern computational equipment allows economical solution to complex problems,

(g) The increased capability for interactive graphics in modern computer equipment. The availability of a wide assortment of devices to record and change simulation output has greatly improved utility of CAD, and

(h) The development of user oriented computer languages that allow designers to communicate with a computer in his own terms without learning an entirely new discipline. The rapid advance in this area is evidenced with the advent of several user/discipline oriented digital computer languages.

The use of Computers can be classified into the classical areas of a CATV system.

(a) Head-end applications,

(b) Distribution system,

(c) Subscriber interface, and

(d) Business aspects.

Within each of these major areas the potential computer usage that is possible using existing techniques is outlined below:

Head-end Applications

(a) Interference analysis by computer

(b) Propagation path analysis and antenna site selection

(c) Computer controlled programming

(d) Computer controlled maintenance

(e) Head-end design aids

Distribution Systems

(a) Computer aided amplifier designs

(b) Computer aided filter and diplexer designs

(c) Automated distribution network design

(d) Network analysis - traffic analysis

(e) Real time scheduling algorithm design

Subscriber Interface

(a) Demand analysis

(b) Response time analysis

(c) Subscriber acceptance of different services

Business Aspects

(a) Marketing

1. Mailing lists

2. Contact reports

(b) Customer billing and accounting

(c) Economic models and growth projections.

2. CURRENT STATUS OF CAD IN BBC APPLICATIONS

The current status of CAD in CATV and two-way broadband communications systems can be characterized as being fragmented into several areas. Since we have structured this report in CATV terminology, this section will also report CAD status in this manner.

2.1 CAD in Head-end Equipment

The use of CAD in CATV head-end design has occurred in several areas. One of the most common has been the selection of microwave sites and the analysis of propagation paths for loss and interference. American Telephone & Telegraph Company (Turner, 1972) has an extensive computer aided system to analyze and keep track of microwave facilities in the U. S. 4, 6, and 11 GHz common carrier frequencies. This data base includes data concerning 11,000 paths that AT&T has analyzed. The system includes provisions for satellites. Head-end manufacturers (Naugle, 1970) generally offer site analysis as a service to the CATV operator as an inducement to procure their hardware. Numerous models exist for the analysis of propagation and interference (McEachen, 1972) that have evolved over the years from work by government and industry, and most manufacturers of microwave equipment have some variant of these models available.

The CAD of components for CATV head-end equipment has not been as well documented, but there are numerous CAD techniques that exist today that are applicable in this area. For example, Grander and Robinson (1970) have reported on an extremely powerful communication simulator language that can be used to analyze and design head-end equipment. This language was developed with flexibility of use by being block oriented where the user merely selects the block functions and inputs the desired attitudes for the block to build the system he wishes to simulate. This system is similar to CSMP in many respects. Other CAD techniques have been reported concerning the design of pulse equalizers that are applicable in head-end equipment design and transmitting systems (Pauley, 1972).

Another application of computer aided design in the CATV head-end has been the preparation of program tapes with digital addressing as reported by Humphreys and Weilen (1972). This system uses a mini-computer to prepare the program material for use at the CATV head-end. This area will undoubtedly expand in a two-way system to allow off-line perparation of the many possible services that may be offered to subscribers.

2.2 CAD Use in Distribution System Design

Computer aided design techniques for the design of a CATV distribution system have been derived from communication system and computer network system analysis techniques. Some of these techniqes have been used to lay out and document systems. One CATV design service is available (Frisch, et al., 1971) for CATV system designers. This system appears to consider the complex decisions such as:

- Selection of head-end sites
- Location of messenger cable
- Selection of trunk distribution points
- Selection of components and manufacturers
- Selection of amplifier output levels and gains
- Location of trunk and feeder cable
- Sizing of cable, location of amplifiers, and assignment of splitters and couplers
- Specification of tilt compensation, padding, and settings for amplifiers
- Assignment of automatic gain, slope control, and temperature compensation
- Specification of subscriber taps
- Location of power supplies
- Provision for future system expansion

This design process results in the location and specification of all

components including cable, couplers and amplifiers; signal levels, cross modulation and noise levels throughout the system; and a bill of materials and documentation. An important side benefit of this design process is the data base for maintenance and operation of the system.

Other CAD programs that have been developed for computer communications systems could undoubtedly have application in CATV distribution design. These systems use existing simulation software to create models of systems. Programs also exist to model error coding techniques (Quigley and Kurland, 1969) that will be necessary in two-way systems. Modeling of trunking systems has been accomplished (Swatz and Smith, 1969) that could have application in CATV system design. Models have been developed for computer networks involving satellite repeaters (Ferrell and Knolse, 1969) that could be used for CATV network analysis.

As suggested earlier, the use of general simulation languages in distribution system design has potential. The availability of these languages from many time-sharing computer companies offers the CATV designer powerful tools to simulate the distribution system, to study the effects of different trunk routing, amplifier designs, and cascading, and to assess subscriber loading on the system.

3. CURRENT STATUS OF COMPUTER AIDED OPERATION

3.1 Computer Usage in Subscriber Interface Systems

A computer controlled two-way system has been designed which uses a minicomputer system as the device to service subscriber inquiry into the systems (Callais, 1972; Callais and Durfee, 1971). This Local Processing Center (LPC) serves as a switching device to control two-way communication on either one or two cables to each subscriber location. A modem is used in conjunction with a subscriber terminal to communicate with the LPC. The LPC controls the interrogation of each

subscriber terminal by polling a block of n terminals. An interesting feature of this system is that the "no subscriber response" is used to determine the subscriber terminal status. The interrogation cycle ends, then any requests are processed in a hierarchical fashion dependent upon a software priority algorithm. At present, the system uses a minicoumputer with 24K, 16 bit words main storage and 256K auxiliary disc memory. A graphics terminal is provided for the system operator to determine system status and usage.

This system offers a wide variety of functions that can be performed both on a local and a regional or national basis. By using digital computer communication techniques, a system operator can offer access to other computerized systems such as reservation, ticket ordering, time-sharing computers, and other services that would make an attractive adjunct to current entertainment services.

Another two-way communications system has been installed in Orlando, Florida, that offers two-way services to subscribers. This system utilizes a minicomputer at the head-end to process subscriber requests, perform the necessary communications and video switching to record data for billing purposes, and to perform error checking of the system. This system also provides services to emergency functions such as medical, traffic, and security systems using the computer as the control and monitoring device.

Other two-way cable communications systems that use audio-visual telephone and push-button dialing devices as subscriber or user terminals have been reported, both as internal business management information systems terminals (Coleman et al., 1971). These systems use the dialing keyboard as the input device to request information or services from a computerized data base.

Two conclusions are as follows:

(a) The available audio-visual telephones have limited graphics and data display capability since it can only display 20 lines of 22 characters each. This limitation places rigid restrictions on the type and amount of data that can be displayed.

(b) Significant software development was required to implement the services (such as order entry information) and to service the user terminal complex.

The technology of computer controlled two-way cable communication is being explored in another system in Reston, Virginia (Mitre Corp., 1972; Volk, 1971). The TICCIT System by Mitre Corporation makes use of computers both for real-time control of the communications system and in the preparation of course material for the Computer Assisted Institution (CAI) services that a subscriber in Reston may request. This system uses a conventional telephone as the subscriber input unit to a central computer. The requests were processed using standard telecommunications access software and the request was passed on to a message switching computer for servicing. This hierarchical concept of computer control is aimed at servicing a large number of subscribers with low response times, since it is distributing the processing load between two computers with a shared memory.

The evolution of this system to two processors to service 100 terminals in the CAI environment may foretell something about the computational loads in a two-way cable system. The necessity to "echo" inputs to the system and to direct the refreshing of the TV receiver adds to the computer load.

3.2 Computer Usage in Business Aspects

The current use of computers in the business aspects of CATV operations has followed the traditional application trends for computer aid operations. Most reported applications have been in the areas of

subscriber billing and marketing applications. A complete management information system that operates in 200 cities with one million subscribers is described in the December 1972 issue of T. V. Communications. Some cable system operators have elected to procure in-house computer systems to perform customer billing and other functions. One such system is described in the February 1972 issue of T. V. Communications. It uses an in-house computer system for work order control, maintenance call summaries, and vehicle maintenance and repair in addition to customer billing functions. Other operators use local service bureaus for computer needs to process customer billing and to perform automated payroll and other functions. As CATV Two-Way Communications Systems develop with a computer system incorporated into the head-end equipment, it can be expected that this computer will be used in a time-sharing mode to perform these business related functions.

4. FUTURE USE OF COMPUTERS IN BROADBAND COMMUNICATIONS SYSTEMS

In order to assess the probable future use of computers in CATV two-way broadband communications systems, one must postulate what system configuration is most likely to evolve in the next 5 - 10 year time frame. From several sources (Jurgen, 1971; Mason et al., 1972; Baer, 1971; Callais and Durfee, 1971; Coleman et al., 1971) it appears that the most likely system design will have the configuration shown in Figure 1. This system is characterized by being able to process and switch various services, both analog and digital, onto the cable distribution system to subscribers. The key addition and change from present day CATV two-way systems is the addition of the communications central computer that not only controls the local r.f. and video processing and output/input switching functions, but also has access via data

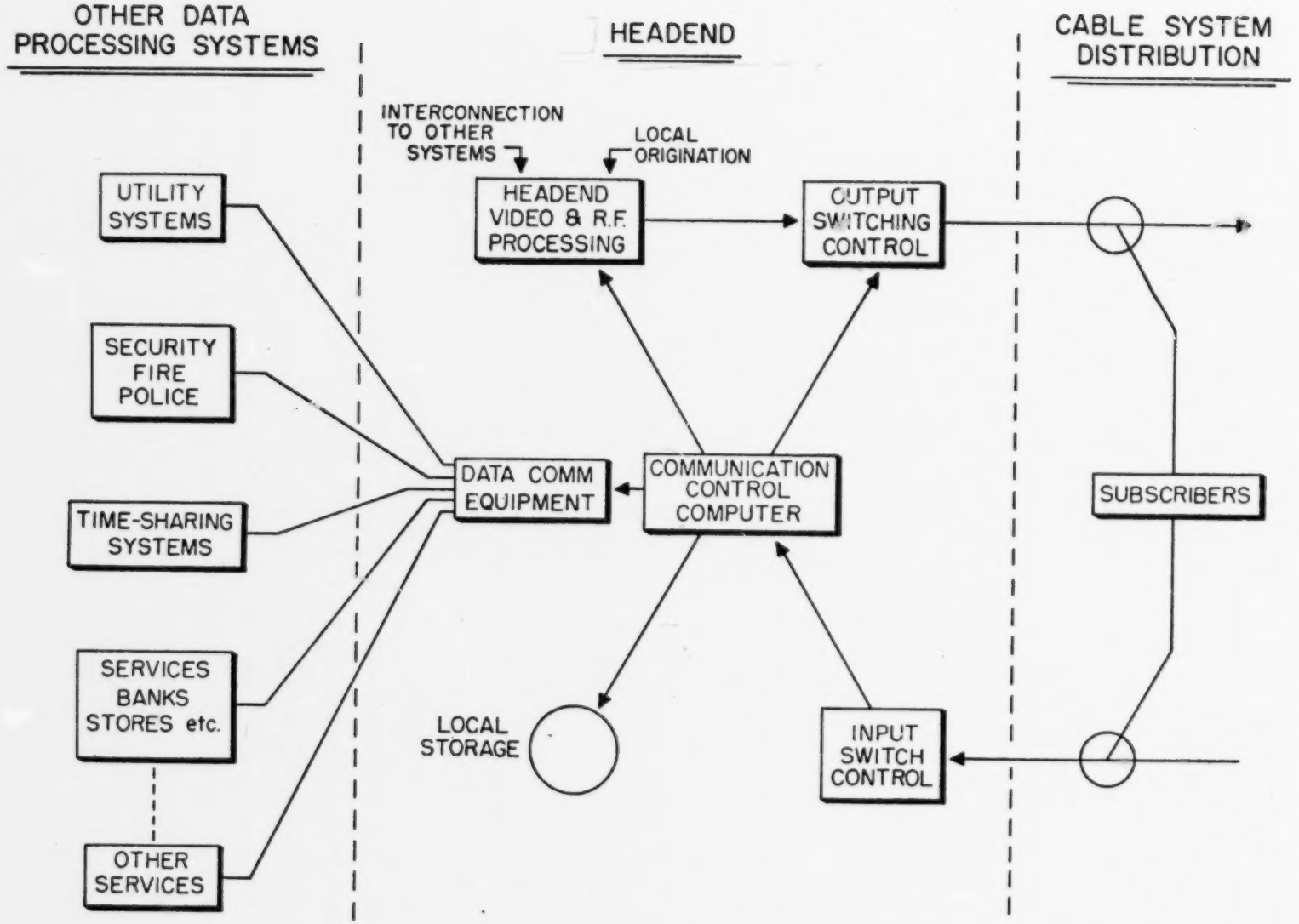
OTHER DATA PROCESSING SYSTEMS
HEADEND
CABLE SYSTEM DISTRIBUTION
INTERCONNECTION TO OTHER SYSTEMS
LOCAL ORIGINATION
UTILITY SYSTEMS
SECURITY FIRE POLICE
TIME-SHARING SYSTEMS
SERVICES BANKS STORES etc.
OTHER SERVICES
HEADEND VIDEO & R.F. PROCESSING
OUTPUT SWITCHING CONTROL
DATA COMM EQUIPMENT
COMMUNICATION CONTROL COMPUTER
SUBSCRIBERS
LOCAL STORAGE
INPUT SWITCH CONTROL

Figure 1

communication equipment to other data processing facilities that can service subscriber request. This design is basically a message switching system rather than circuit switching. Some local processing of subscriber requests could be accomplished and, certainly, usage data for billing functions would be processed locally. With this conjectured system, the future use of computer aided design and operation will be addressed.

4.1 Computer Aided Design

This section discusses the probable future areas of computer aided design and operations in broadband communications systems.

4.1.1 Component Design

The design of components for CATV has all of the attributes of a complex design problem. These are as follows:

Broadband frequency response

Linearity

Temperature compensation

Low cost

Easily maintained and alined

Can be mass produced

Modular for system growth

An engineer faced with these attributes for a design requires all of the mechanization for design that he can get. The problem is further complicated by a massive data base of descrete and integrated component suppliers on which to base a design. The ability to store these component characteristics in a computer data base for injection into a postulated design is an important feature for the design engineer.

Component designs for CATV systems involve:

(a) Amplifiers

(b) Filters and diplexers

(d) Connectors

(e) Directional couplers and splitters

Most component manufacturers in these areas are using some form of CAD to engineer their products. These CAD applications result in faster design turnarounds and being able to customize designs rapidly for certain system applications. For example, in amplifier design, several computer manufacturers supply Electronic Circuit Analysis Programs as a part of their free software library. Such programs, as IBM's ECAP and Los Alamos NET-1 program have been widely distributed, modified, and renamed within the electronic design community.

In component design, the continued use of CAD especially in the area of MSI and large scale integrated (LSI) circuits is expected to grow. The design and manufacturing layout of these devices is so complex that computer design assistance is mandatory. Some semiconductor manufacturers are offering design services at CAD centers where the engineer can interactively communicate his desires to the computer system via a graphic terminal to achieve custom designs. These techniques and services are expected to grow rapidly and will offer the CATV component designers additional capability to achieve higher performance and lower cost designs.

4.1.2 Computer Design

The design of a CATV two-way communications system control computer can be expected. This design will make use of many existing simulation techniques to determine the proper architecture for this computer system. A principle concern will be the handling of time-critical processing (interrupts). It is expected that this design can gain valuable information from the ARPA interface message processor (IMP)

design. Simulation of the necessary software will also be very critical to this design. The trade-off analysis of firmware vs. software will be very critical to the performance of this industry dedicated computer.

As the computer industry moves to higher levels of hardware integration, it is possible to design classes of machines that have hardware - software macro-functions tailored to a specific industry need, but yet retain a general architectural similarity. Computer architects have called such systems "polysystems" or polyprocessors", and it is forecast that the late fourth and fifth generation computer systems will have this architecture (Joseph, 1972).

Some of the expected characteristics of a CATV two-way communications system computer are as follows:

Hardware Attributes:

(a) System felixibility-modularity

(b) Real-time hardware interrupt hardware--structured in priority hierarchy

(c) Instruction set optimized for character-bit manipulation

(d) Capable of addressing large memories--virtual memory capability to retrieve from large auxiliary stores

(e) Very high availability

(f) Easily maintained by operating system technicians

Software Attributes:

(a) Real-time operating system

- o Queue control
- o Line handling
- o Storage management
- o Subscriber terminal control
- o On-line test and diagnostics
- o Error control and recovery for lost traffic-line failures

- o Checkpoint restart
- o On-line recording of usage and accounting data
- o Real-time process construction from macro-library

(b) Off-line support

- o Loader-linkage program
- o Communications oriented compiler and process construction language
- o Large communications oriented macro-library

4.1.3 System Design

In the area of system design, the principal application of CAD would be in network analysis and in the design of the head-end and distribution system.

For example, the design of the head-end system will probably involve an antenna site selection based upon propagation path analysis and interference analysis of the surrounding electromagnetic environment. Use of CAD techniques in these areas is widespread. A great deal of this work has been sponsored by the military and Bell Telephone, and is available in the public domain. Several companies have developed in-house programs to aid their system designers in the selection of proper antenna and head-end sites.

Network analysis and design for a large network is almost a necessity. This area has recieved most of its support from the military, commercial computer time-sharing companies, and the Bell Telephone system. There are several important areas of additional research that are required to bring this area to the same level of experience as the component, propagation, and interference analysis CAD applications. These are addressed later in this chapter.

4.1.3.1 Network Analysis and Design

The use of computer-aided design has been very pronounced in the area of network analysis and design for computer/communication networks. The principle reason for this emphasis has been the evolvement of digital communications on the telephone system and the emergence of the time-shared computer. One of the most documented network designs and one that has been implemented and tested is the ARPA network. This network probably most nearly approximates the expected conditions that one would encounter in netting the existing CATV systems together into a national network. The ARPA network is characterized by the following:

(a) Dissimilar equipment

(b) Diverse users

(c) Many different software systems

(d) Large data bases

(e) Geographic diversity

The approach used by the ARPA designers (Frank et al., 1972) was to adapt a message switching system design rather than circuit switching so that the network topology would remain relatively constant. By the nature of the desired network, it is a distributed system rather than centralized. There are still serious questions on this issue, although more experience is required, most large systems today use message switched distribution, with the obvious exception of the telephone system.

The ARPA design approach was divided as follows:

(a) Design of nodal store and forward switches (interface message processors)

(b) Network topological design

(c) Design of the network protocol

(d) Design of a system model and network performance measurement scheme

The modeling approach considered message queuing as the most important system parameter. This translates into subscriber response time in a BBCS design and therefore would be germane to this discussion.

Other parameters that are considered in the ARPA network design are as follows:

(a) Routing philosophy

1. Local control of message routing
2. Global or central control of message routing

Routing control in a BBCS may have to consider both message switching and circuit switching since in a two-way system both analog and digital singals are present (assuming that a PCM conversion is not made to conventional TV signals) and t is also implies a hierarchy of routing control similar to the current telephone system.

(b) Error control

Network design must consider the type of errors expected and some predicted frequency of occurrence since this protocol will influence both message traffic and routing control. Error coding techniques used will affect message traffic since the most prevalent coding schemes involve adding a cyclic redundant code to the digital message. Upon detection of an error (usually due to burst noise in the communications channel), the most widely used recovery technique is simple retransmission of the message up to n times. If the message is not accepted by the receiving processor after n times, the channel is considered defective and maintenance action is initiated. This is the current ARPA error recovery approach.

(c) Reliability design

This area considers:

1. Communications channel failure

2. A nodal failure--in CATV terms, a headend failure

3. Both

The network routing protocol must be able to develop alternative routes within some acceptable recovery time. This design requirement in a BBCS would probably become, along with response time, the most important network parameter. Very little effort has been devoted to this area in large network design.

Another approach to a large network has been the design of the National Security Dealers Quotation System (NASAQ) network. This system approximates a BBCS and is characterized as follows:

1. Central site computer system duplexed for reliability
2. Regional message concentrators
3. Large number of inquiry terminals
4. All new real-time software for both inquiry and control of the network

Another consideration in large network design is how to distribute the information files within the network. In the case of BBCS, these files will contain diverse material with many forms of access and updating. Some effort in this allocation problem has been accomplished (Casey, 1972). The approach has been to assume nodal access points for query traffic and that every node is connected. The principal concern is the update problem in a distributed file system. The number of copies maintained can seriously degrade the performance of the network as the file update traffic increases. This area requires more research as it applies to BBCS due to the diverse nature of the possible source material. Extensions to the work done on ARPA and other time-sharing networks is required to solve this complex allocation problem.

Another area of concern in network design and analysis is the impact of satellite repeater stations upon both network topology and technical and cost performance (Ferrell and Knolse, 1969). The concern

here involves the characteristics of a mixed transportation system and its effect on network performance in a two-way BBCS. Questions about propagation delay, fading, coverage, etc. should be postulated, modeled, and analyzed using CAD techniques. This area certainly requires additional research from both industrial and governmental laboratories.

4.1.3.2 Real-Time Scheduling Algorithms

Operation of a real-time computer-controlled network involves the response to external signals and requests for service in some orderly and timely fashion. Response to these inquiries must be made in some reasonable time. For example, a subscriber request for service must be processed at the head-end of the BBCS and some indication given that his request has been honored and is being processed or that he has made an illegal or incorrect selection and should repeat his request. It seems reasonable that a maximum response time for a subscriber should be in the 2-3 second time frame. If one accepts this system constraint, then the development of a suitable software scheduling algorithm for Time Critical Processes (TCPs) is a fundamental problem. The scheduling of TCPs has been the subject of study in several areas: radar scheduling algorithms, real-time military data systems, and process control systems to name a few. This problem has been addressed in the use of time-sharing networks where customer response is a key parameter. These networks typically use a time division multiplex approach with each possible part being polled on a fixed template pattern for any response or message. Other system approaches include the ARPA computer network, which is a message switching system that has been extensively studied and measured. The ARPA network is discussed in other areas of this report.

Little theoretical work for large networks has been accomplished outside of the telephone industry. Formal scheduling theory of TCPs in

particular has not received the emphasis that it deserves in large network analysis. Extensions of the work of O. Serlin (1972) in arriving at a consistent theory for TCPs in a large multiprocessor network is needed. In the cited reference, the foundation of an approach has been initiated. Extensions of this work to apply to large BBCS with both circuit and message switching functions is needed. Several algorithms for scheduling TCPs have been formulated:

(a) The intelligent fixed priority

(b) Minimal time slicing

(c) Relative urgency

Very little testing and measurement of these approaches have been accomplished from a modeling and theoretical viewpoint in connection with Ballistic Missile Defense Systems. These models are primarily of the intelligent fixed priority type where dynamic changes to the fixed priority are not considered due to the short time frame of the needed scheduling of TCPs.

In a large BBCS, the development of suitable algorithms for TCPs is a critical problem. Once the topology of the network has been established (this topic is addressed in another section), the software to control the subscriber response time under worst case traffic loads becomes a paramount issue. This area requires both additional theoretical study and use of computer aided design models and simulations to fully evaluate the impact of TCP algorithms on the system utilization. This area of research can utilize both government and industry resources effectively.

4.1.3.3 Digital Geographical Design of CATV Systems

In the future design of BBCS, the use of geographical data that have been digitized by government agencies like the Census Bureau can be used for route selection design and market evaluation. The Census

related information of the large metropolitan areas has been digitized with geo-coding so that address matching can be accomplished. This would allow a designer of a BBCS to lay out a system completely from a computerized data base. The obvious combination of CATV equipment characteristics furnished as input to such a computer program would yield a complete design with documentation for the system. The use of aerial photography properly digitized in conjunction with other demographic data is feasible to aid the CATV system designer. Such techniques have been used to locate and plan other urban transportation systems. It is expected that this area will develop into a new aid for the CATV two-way communications system designer.

4.2 Computer Aided Operation

This section discusses the Computer Aided Operation of a BBCS. This area is one that will grow as more two-way communications capability and subscribers are added to systems. Many areas of new application of the computer will be made as these systems grow and expand into regional and national networks.

4.2.1 Computer Aided Operation and Maintenance

One area of future growth in a CATV two-way system utilizing a computer at a head-end or nodal point is the utilization of the computer for system operation and maintenance. This topic was addressed by Baer (1971) and is extended here. Modem amplifier designs have the capability of being remotely addressed and controlled in a distribution system. The capability to remotely adjust the automatic gain control (AGC) as a function of temperature, along with other characteristics offers the system operator advantages such as reduced travel, less manpower, more accurate records of service, and long term system performance characteristics to improve and aid system maintenance.

Certainly, the computer system will be used for subscriber usage reports, billing, inventory, and other management functions to aid the system operator. The use of the computer system to program cable activities that "protect" local off-the-air systems is another possible use of the head-end computer system.

4.2.2 Computer Aided Decision Making

The use of computers in the area of decision making has been primarily in the economic and geopolitical areas in BBCS. The use of massive data from government agencies, such as the Bureau of Census, to model geographical/social impact of CATV/BBC has a great deal of merit. Such computer models tend to be rather oriented to the specific case under study and not general purpose in nature.

4.2.3 Economic Models

Extensive use of computer aided economic models has been used in the urban cable system studies that have been performed to date (Mason et al., 1972; Johnson, 1972). The massive data gathered in these studies must be reduced to some meaningful summary information for ease of understanding. The use of many sources for gathering the necessary data is a complicating factor. The mechanization of the data input helps this problem by forcing some standardization of data collection.

The use of computers for determining the economic structure of urban communications system will continue and expand as these systems grow in complexity. The use of the many sources of computerized data will undoubtedly increase. The use of Census Bureau data will grow. In this area the Census Bureau can probably supply tremendous supporting data to CATV designers concerning the economic feasibility of a system by utilizing the statistical profiles prepared at and during every census

period. Data concerning income level and U. S. geographical distribution will indicate possible subscriber penetration, the rate charges that would be acceptable, and the probable services that would be desirable.

Guidelines for the collection and use of Census Bureau data should be established so this data will be of maximum use to the CATV designer. For example, information concerning the number, type (black and white or color), and age of TV sets in a neighborhood could be collected by Census hopefully without undue invasion of privacy. These data would be a useful input to economic and technical models of a system being designed.

5. SUMMARY

5.1 Current Use of Computers in CATV

The use of computers in CATV today can be categorized into two areas:

(a) Computer aided design (CAD)

(b) Computer aided system operation

The computer aided design of electronic systems has grown very rapidly in both system and component manufacture due to the availability of powerful computer languages and machinery that is capable of producing cost-effective solutions. Some of this capability is being applied in the CATV industry today, and much more spin-off and new developments are expected as CATV moves toward a full two-way communications system with regional and national interconnection.

The computer aided system operation is in the research and development stage with several experimental systems using computers in CATV head-end equipment to service subscriber requests. This area is expected to grow very rapidly as CATV and two-way communications become more complex, offer more services, and expand into regional

and national distribution of program material. This development can make use of the technology gains of the telephone and computer communication industry as a great deal of experience in national networking and distribution has been gained in the past 20 years.

This report discusses both aspects of computer usage in present and future CATV systems, although the boundary between CAD and computer aided operation is sometimes vague. The intent is to assess the present state-of-the-art of computer applications to CATV and two-way communications (broadband communications) and to project other possible uses of existing and new technology to aid in the design of these systems. Technical problem areas are cited and recommendations for further study are made.

The use of computer aided design (CAD) and operations in the CATV industry can be characterized as fragmented. The use of simulation models for system design has been limited to specialized areas such as head-end locations or distribution systems. Simulation of an entire system from head-end to subscriber terminal has not been achieved, although the techniques and most software exist in one form or another to accomplish this task.

Computer aided design has been used in the following areas of CATV design:

(a) Antenna location and propagation path analysis and interference analysis

(b) Amplifier designs

(c) Component designs

(d) Design of subscriber networks for two-way systems

(e) Distribution system designs and documentation

Some of the technical problem areas that exist in the CATV industry today are:

(a) Development of adequate complete system modeling and

simulation techniques for large distribution networks,

(b) Development of theory and simulation techniques for the file storage and allocation problems that will occur as the CATV distribution system becomes more complex,

(c) Analysis of the interface and interconnection problems that will occur where existing CATV systems are netted together,

(d) Real-time software analysis for two-way systems to handle time critical processes and error detection and recovery,

(e) Development of a central computerized data base for CATV technical data, available to the industry.

5.2 Recommendations for Further Research

The most urgent need to support further research is the establishment of the computerized data base for CATV technical data. This effort is a proper role for the CATV industry with government assistance. This central data base could be an information retrieval system available via remote terminals, housing technical data concerning system components and available software that can be used for system design. This system can be patterned after the ARPA network where those users that have in-house computers could participate in the data and software resource sharing. Services from proprietary data and software sources could also be offered to the CATV industry via this mechanism. This dedicated system could also offer business computer services such as customer billing, payroll, etc. to small CATV operators on a fee basis. This service can be properly administered by the CATV industry using third generation computer techniques and could have far-reaching effects on the growth of the industry due to the simple aggregation of industry technical data in a central location.

Research into two other problem areas of broadband communications systems should be undertaken: (a) real-time software analysis

in the form of continued development of a formal theory of real-time processes, and (b) file storage research in the areas of the file allocation problem and mass storage techniques (optical and magnetic).

These two areas are closely related, since the servicing of real-time requests is a function of the time to retrieve the desired information from a storage file. The design of real-time information retrieval systems is in its infancy today. With the advent of two-way communication systems via existing or planned cable systems, this area will be the most expensive and time consuming area of system design. The operation and maintenance of the more complex systems will also require more highly trained and diverse skills (such as computer system programmers) than present day systems. Hence it is recommended that the CATV industry and government laboratories embark on a well planned research program in this area.

Finally, research should be continued in the development of complete system simulations and models for large distribution networks and associated interface and interconnection problems. This research can draw heavily on experience gained in large computer communications networks currently in operation. Many tools for simulation of discrete and continuous systems that can be utilized for network analysis have been developed. The use of these tools to analyze both network hardware and software for a large CATV two-way communications system should be the subject of an in-depth research project.

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Uses of the computer in the design and operation of broadband communication systems are discussed. The current status of computer aided design is reviewed, with consideration ranging from components to total systems and networks. Future applications of computers to design, simulation, operation, maintenance, and economic modeling and decision making are introduced and assessed. Lastly, recommendations are made for necessary future research and development.

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